Absolute Conditioner for Fabry-Perot Microsensors

Michael D. Pocha
(925) 422-8664
pocha1@llnl.gov

High-fidelity flight tests are required by the weapons stockpile stewardship mission to assure weapon viability without underground testing. Additionally, embedded sensors in future reliable replacement warheads (RRWs) will monitor state-of-health and ageing. These applications require miniature, minimally invasive sensors and readout systems. Sensors also need to be optically read out to reduce exposure of sensitive components to electrical energy. Several different sensors are available to measure parameters such as acceleration, strain, displacement, pressure, and temperature, at various locations within test assemblies. This effort is focusing on two important new sensors, an optical gap gauge (OGG) and an optical force probe (OFP). While a variety of miniature sensors (commercial and custom made) are available, current signal conditioners (readout systems) are big and bulky (usually rack mounted), and unacceptable for LLNL applications.

Project Goals

This is the first year of a two-year project to reduce to practice several concepts for miniature OGG and OFP sensors, as well as techniques for implementing the necessary absolute measurement signal conditioners for these and similar sensors. The sensor fabrication was begun in this first year and will conclude with demonstration of working devices in the second year. Our goal for the absolute conditioner was to demonstrate, in the laboratory, our concept for the miniaturizable conditioner, for the first year, and to explore miniaturization techniques in the second year.

Relevance to LLNL Mission

High-fidelity flight tests to assure weapon viability without underground testing and implementation of future RRWs are central to the LLNL weapons stockpile stewardship mission.

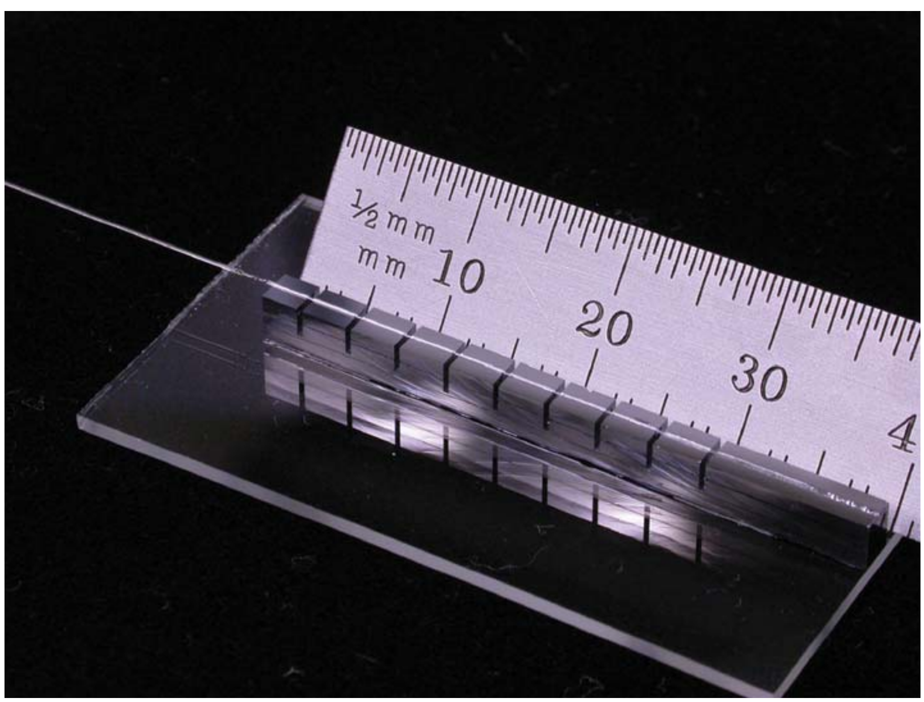

Figure 1. Optical gap gauge spacers for enhanced sensitivity.

FY2006 Accomplishments and Results

Fabrication of the OFP, as part of this effort, requires several new methods of silicon processing, sensor assembly, and packaging. Accomplishments were made in all these areas. A commercial readout system has also been specified and purchased to help the testing of the new OFPs.

A major concern is joining of the optical fiber to two silicon halves that form the transducer. Specifically, anisotropic plasma etching of silicon has been defined to form grooves to assist with fiber mounting. Brazing of the sensor components has also been defined to improve joints used to date. Assembly jigs and methods have been created to assist handling of silicon parts and sensor assembly. Finally, packaging methods have been defined to encapsulate the OFP. The new OFP will have a total thickness of 140 µm, is thermally compensated, can be multiplexed with multiple devices on a single fiber, and is resistant to particulate or other contamination.

The OGG fabrication has been modified to scale its sensitivity. Used as a Fabry-Perot (FP) sensor, the OGG requires the separation between the fiber's core and the sensor's beam to increase to achieve greater displacement sensitivity. Processing to accomplish this has been demonstrated.

The absolute conditioner effort included fringe visibility experiments; fiber preparation; a gap movement linearity study; full conditioner modeling for simulation of light sources and predictive understanding of practical limitations imposed by several optical components; and finally, testing the effectiveness of various computational algorithms for extracting the sensor gap (the key measurement parameter) from the raw fringe data. A key result is that a preliminary model, which can be implemented with commercial components, reduces the conditioner volume to approximately 3 in^3. We estimate that a further order of magnitude in volume reduction is possible when several custom MEMS components are fully implemented.

Figures 1 to 3 illustrate our results.

FY2007 Proposed Work

New OGGs of varying displacement sensitivities will be fabricated. The fabrication and testing of the new OFP will continue. Implementing a fully miniaturized version of the absolute conditioner is an extensive task beyond the scope of this project. But, we will explore miniaturization technology, and attempt to fabricate the reduced-size functional model that was created in FY2006.

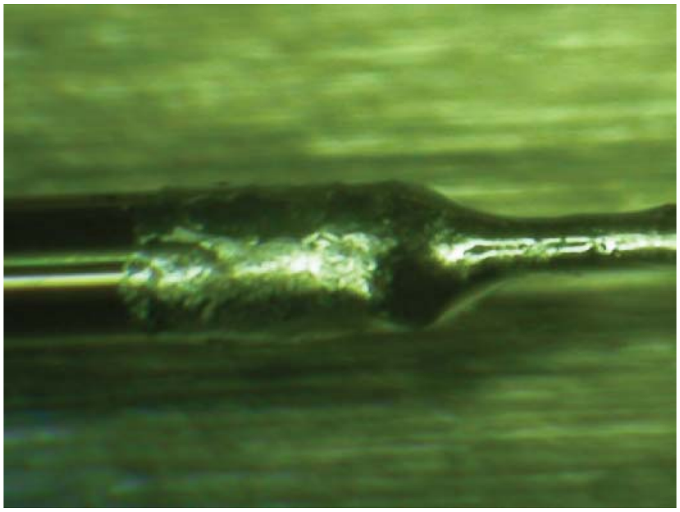

Figure 2. Fiber braze joint, bonding fiber to capillary for use in FP-based microsensors. Brazed and bonded joints offer long-term sensor stability and hermetic sealing.

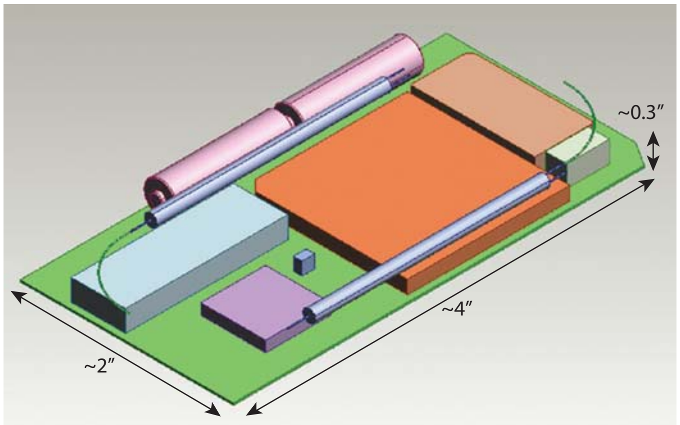

Figure 3. Representation of repackaging of commercial components, which can lead to a readout system that fits within a 3- in.^{3} volume.